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# Extended Power Uprate (EPU) Vibration Assessment and Vulnerability Review

October 25, 2004

# Agenda

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- Introduction
- EPU Vibration Assessment
- EPU Vulnerability Review
- Sample Probes
- Planned Actions/Outage Scopes
- Closing Remarks

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# Introduction

James Meister
Vice President, Nuclear Services

# Quad Cities (QC) Steam Dryer Replacement Project

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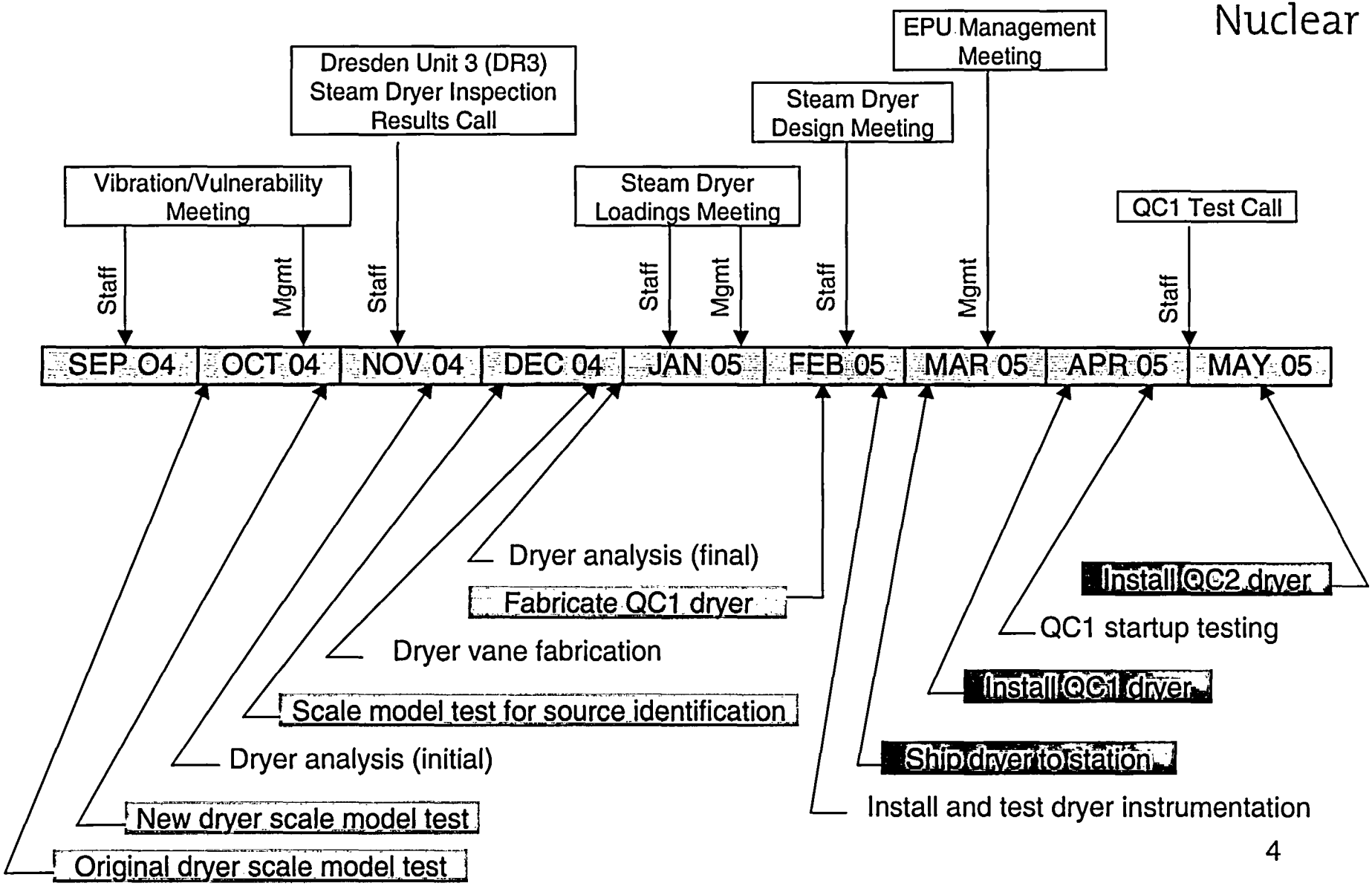

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# EPU Vibration Assessment

Sharon Eldridge
Corporate Engineering

# Topics

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- Vibration Evaluation
- Timeline
- Exelon Actions
- Original EPU Monitoring Plan
- Vibration Evaluation/Scope
- Purpose, Scope, and Methodology
- Results
- Independent Reviews
- Summary

# Vibration Evaluation

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- The purpose of the vibration evaluations was to provide assurance that potentially affected components would perform acceptably for at least a full 24-month cycle at EPU full thermal power operation
  - All evaluations and testing are completed except for the Target Rock Safety/Relief Valve (S/RV)
  - Implementation of actions is either planned or complete to support return of QC Units 1 and 2 to full EPU power operation
  - DR evaluations support continuation of full EPU power operation

# Timeline

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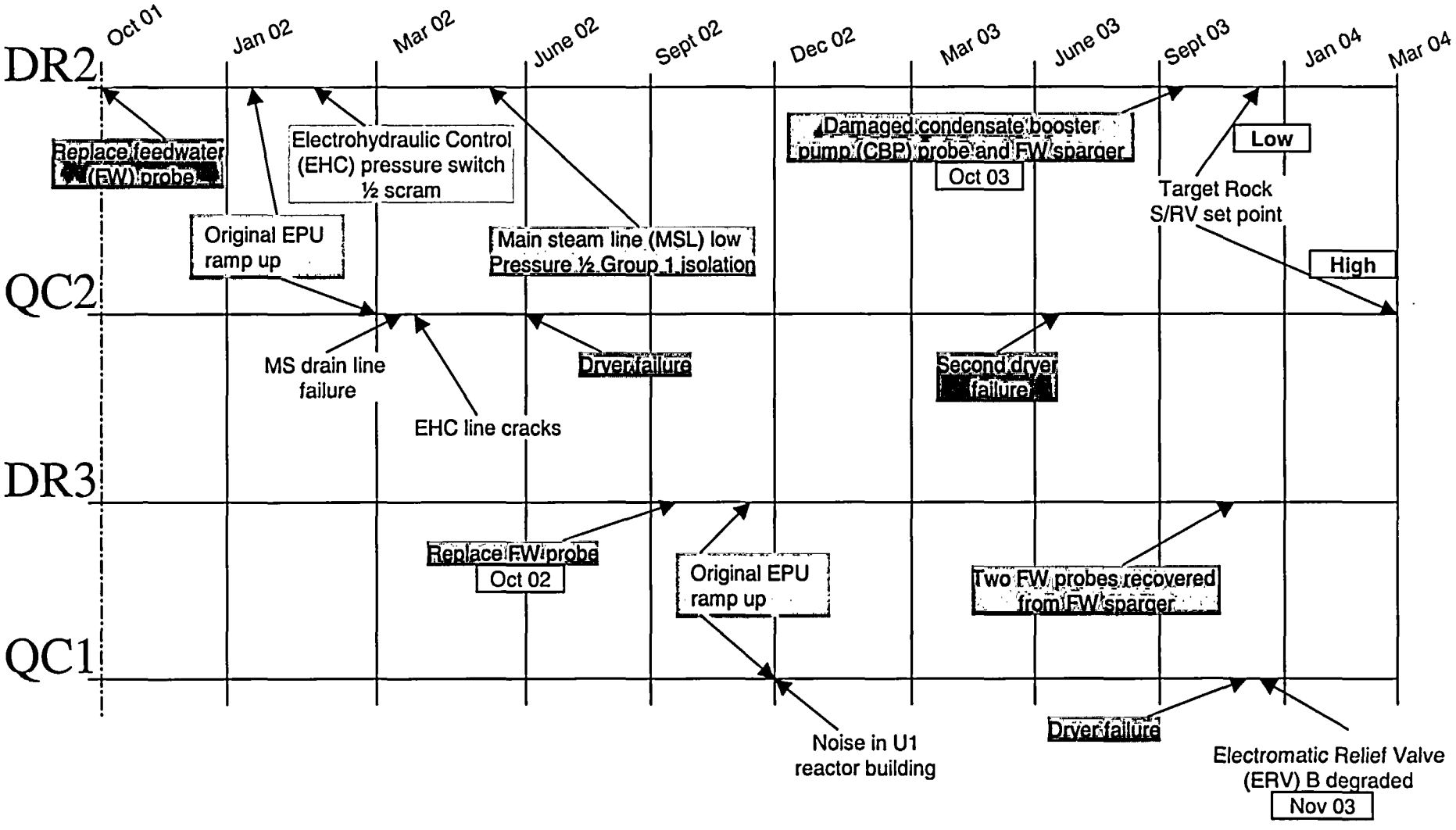

# Exelon Actions

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- Exelon established a comprehensive action plan which included three teams to identify actions to prevent future EPU failures
  - Steam Dryer Team
  - EPU Vulnerability Team
  - Vibration Team

# Original EPU Monitoring Plan

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- DR/QC EPU initial vibration monitoring plan was based on industry guidance for piping
  - Utilized accelerometers on large bore piping supports
  - Focused on piping, both large and small bore, to prevent failures
  - Acceptance criteria for piping vibration limits based on American Society of Mechanical Engineers criteria (i.e., OM Part 3)
  - Approach to implementing the monitoring plan contributed to failure of MS low point drain line at QC2
- Industry guidance for components was also utilized
  - Pump vibration monitoring conducted
  - Relied on component surveillance testing to ensure acceptability

# Vibration Evaluation/Scope

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- During QC1 dryer repair outage in November 2003, the 3B ERV actuator was identified to be damaged
  - Root cause investigation was initiated
  - A detailed inspection scope was developed and implemented for both QC and DR to determine "extent of condition" and identify any other potentially vulnerable components
- Exelon completed comprehensive walkdowns of plant systems and components at DR3 and both QC units to bound the extent of condition
  - The DR2 refueling outage occurred prior to November 2003 discovery
  - Evaluations for DR2 were based on surveillance feedback information and EPU power ascension vibration data
    - ERV actuator inspections
    - Main Steam Isolation Valve (MSIV) work during outage
    - Miscellaneous MSL support inspections

# Vibration Evaluation/Scope (cont.)

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- A detailed list of potentially vulnerable components was developed for each evaluation
  - Each component was dispositioned by evaluation, walkdown results or testing
- EPU related vibration issues identified as a result of these walkdowns include:
  - Remaining three ERVs degraded (QC)
  - Limitorque operator limit switch degraded (QC)
  - Various pipe support mechanical connections with loose nuts and bolts (DR/QC)
- Based on the walkdown results, accelerometers were installed on susceptible components for data collection and reevaluation
  - MSIVs
  - ERVs
  - Various limit switches, including Namco-type on MSIVs
  - SRVs and Target Rock S/RV
  - Valve operators (Limitorques)

# Purpose, Scope, and Methodology

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- Component/system responses for full EPU thermal power operation were assessed using:
  - Vibration data collected throughout the available range of power operation
    - Vibration data obtained during ramp up to full EPU power level for each of three units (fourth unit was already at full EPU power)
    - Data was extrapolated to correspond to levels expected at full thermal power and utilized in evaluations
    - Actual vibration levels will be measured when the units stabilize at full power to confirm the assumptions made
  - Industry operating experience
  - Component failure/preventive maintenance (PM) history
  - Analytical modeling
  - Testing at Wyle Laboratories
  - Inspection results

# Results
## General Assessment

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- Evaluations concluded that all components are acceptable as originally designed for full-cycle operation at full EPU thermal power with the following exceptions:
  - ERV susceptibility to vibration at QC required upgrades of vulnerable parts
  - Target Rock S/RVs showed vibration wear degradation at both QC and DR
- The team identified additional recommendations for enhancements in testing, monitoring, and refueling outage inspections
  - An example is confirmatory vibration testing of Limitorque and Namco limit switches (completed successfully)

# Results
## ERV Components

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- Wear mechanism is a result of a local structural mode of the solenoid plunger assembly
  - Response due to assembly floating on spring
- ERV response for full EPU power operation was evaluated
  - Detailed finite element models were completed for the ERVs
  - Testing performed at Wyle Laboratories to determine/confirm failure mode and to test proposed modifications
  - Over 50 individual tests performed to validate wear mechanism and proposed valve/actuator modifications

# Results
## ERV Components (cont.)

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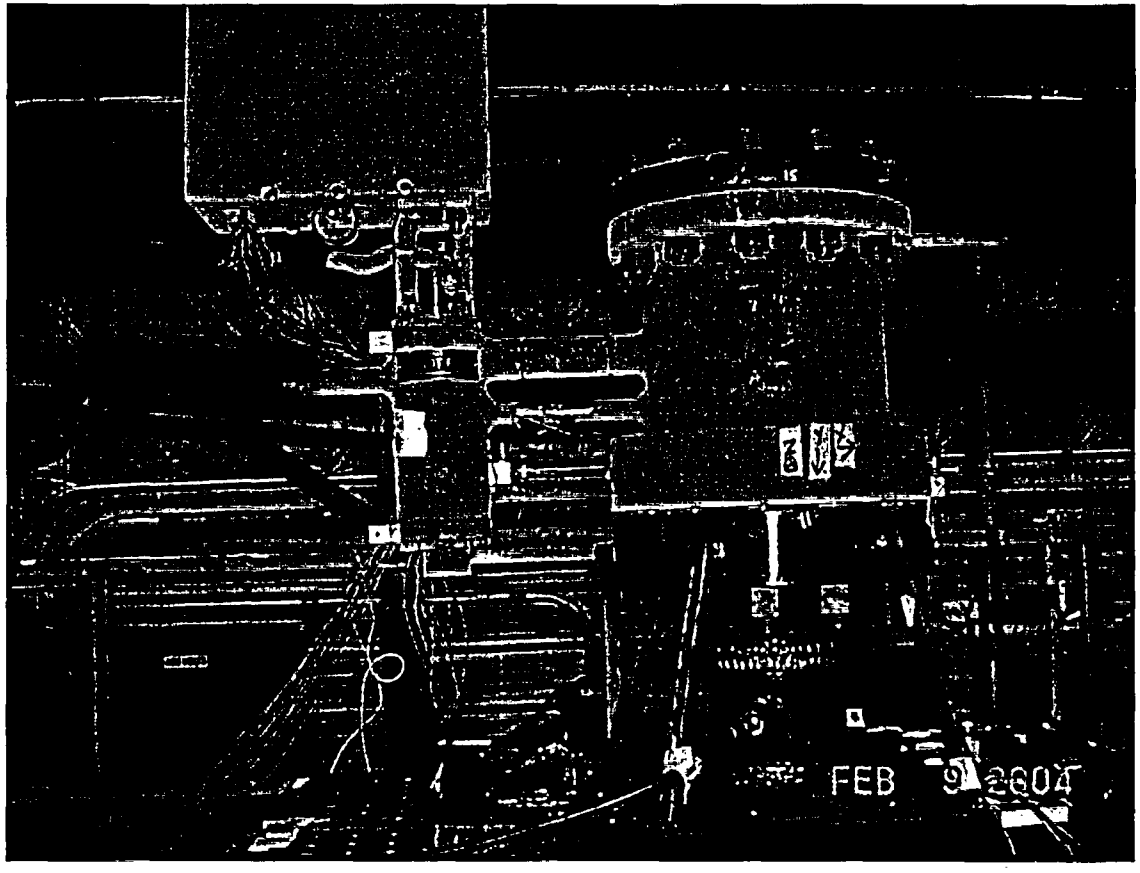
- The four ERVs have virtually identical assemblies, which consist of the main ERV valve body, pilot valve, and solenoid actuator



# Results
## ERV Components (Actuator Internals)

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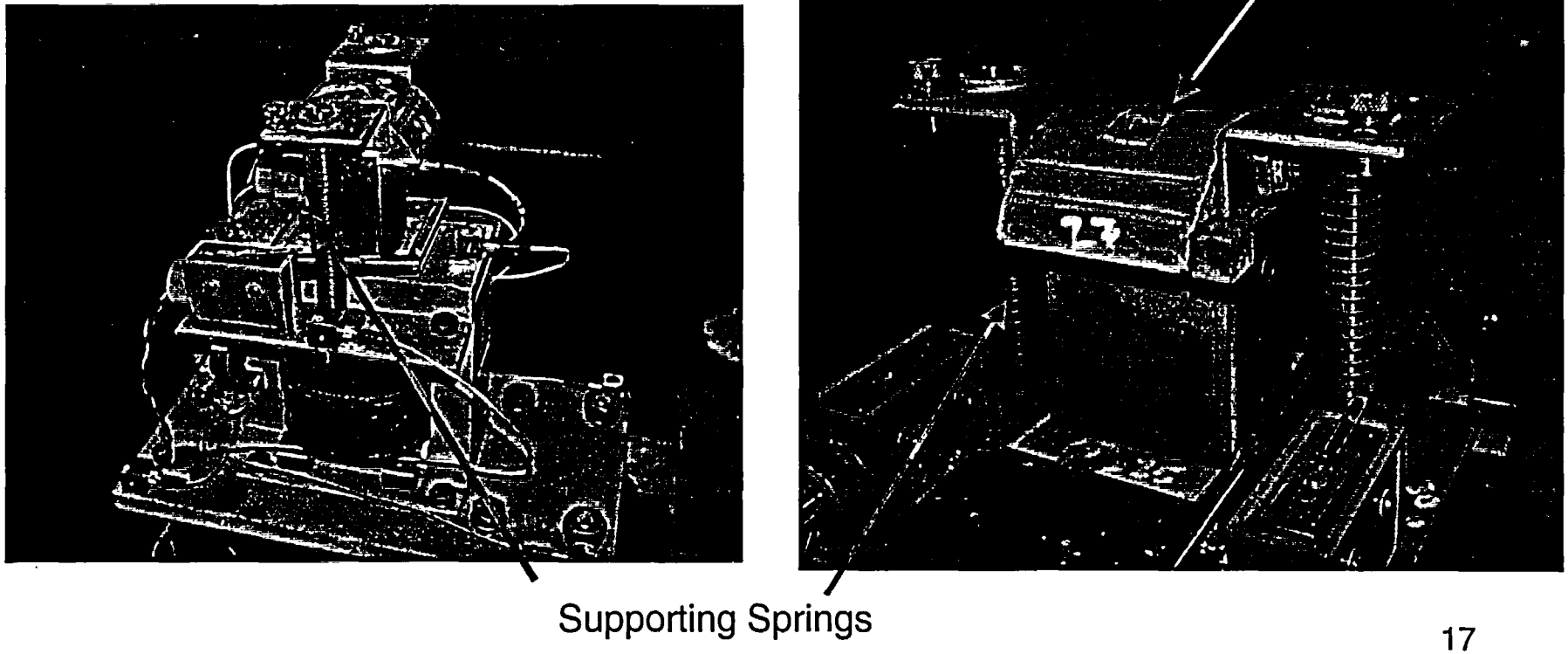
- Wear mechanism is result of a local structural mode of the solenoid plunger assembly
  - Response due to assembly floating on spring



# Results
## ERV Components (Worn Bushings)

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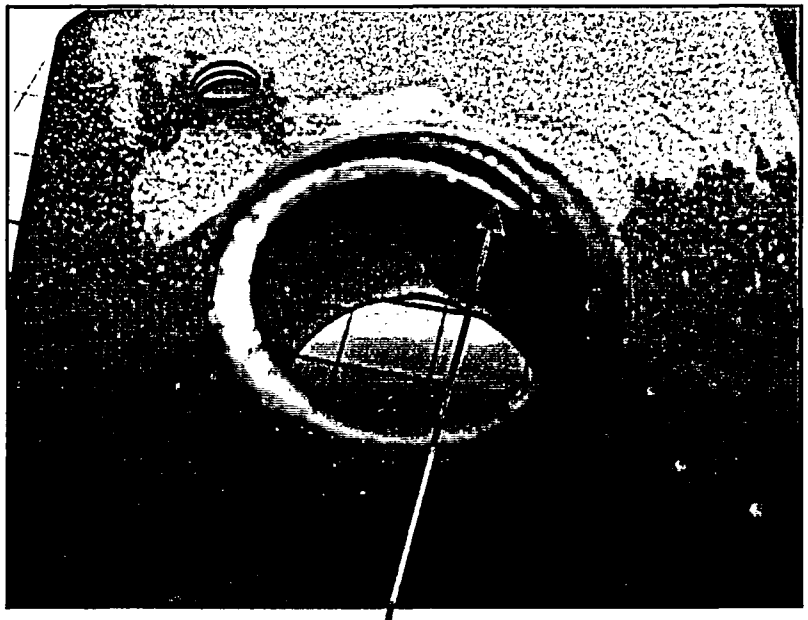
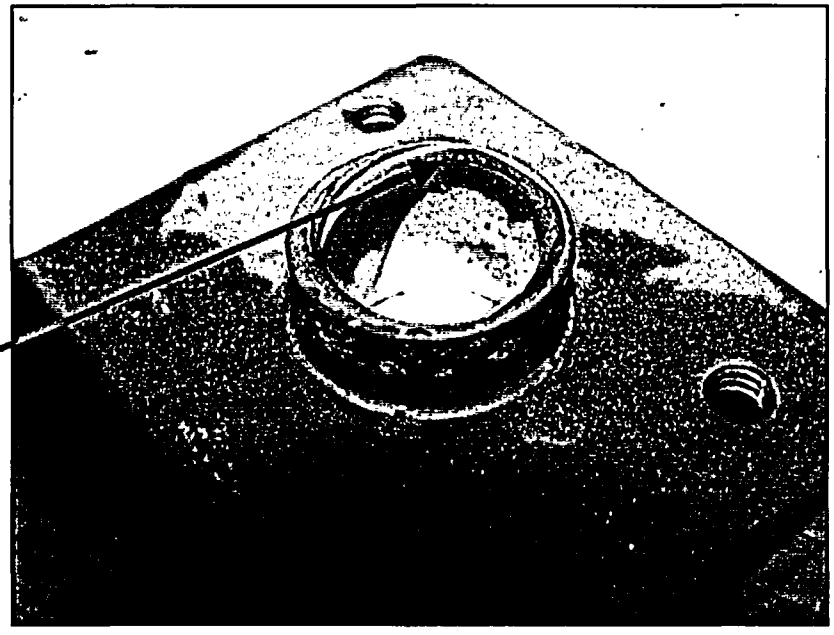


Brass bushing



Groove worn by spring point

# Results
## ERV Components (Acceptability)

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- Vulnerable components within the actuator assembly are being modified
  - Material changes implemented for parts which have historically exhibited unacceptable wear
  - Inconel X750 bushings and guide rods being installed
  - Springs are being chamfered to remove hard edges which cause damage
- Vibration endurance testing completed and provides assurance of full-cycle operation with only inconsequential wear of the affected components
- PM revisions were made to ensure that inspections/rebuilds are performed every cycle until adequate performance is assured
  - Standard PM feedback/revision process will be used

# Results
## Target Rock S/RV

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- As-found testing on QC2 Target Rock S/RV resulted in +6.8% lift point
  - Disassembly and inspection determined that wear of the bellows cap caused spring resistance to increase
    - Groove worn in bellows cap caused spring to bind
    - Additional force required to open valve is approximately 70 pounds
- Test results for two DR Target Rock S/RVs: –3.6% (with EPU operating history) and –1.4% (without EPU operating history)
  - Both valves exhibited wear patterns similar to QC valves

# Results
## Target Rock S/RV

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- Shaker table testing has been performed to confirm wear phenomena driver
  - Testing produced similar wear to the as-found condition
  - Conclusion is that the wear is a function of the spring and cap configuration combination and the materials installed
    - Phenomenon is not exclusive to EPU operation
    - Enhanced tolerances and materials on first stage pilot spring and cap combination being implemented
      - The solution has been developed and tested, and will be installed in DR3 during the November 2004 refueling outage
    - An additional enhancement is being evaluated, including any necessary prototype testing

# Target Rock Pilot
## Bellows Cap and Spring

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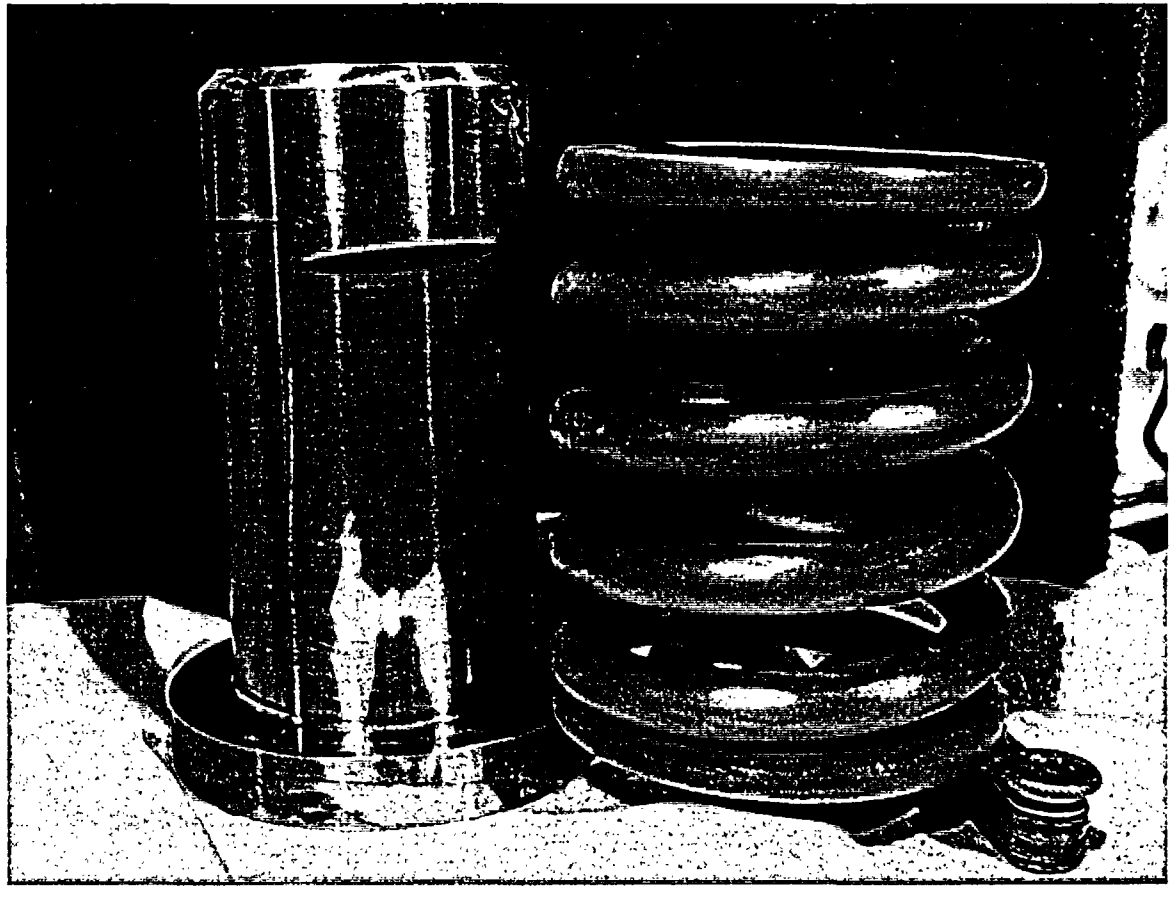

In-service bellows cap and spring

# Results
## Other Testing

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- Namco limit switches tested with plant level data for vibration endurance
  - Results showed acceptable performance
  - Matched previous analytical results

- Limitorque limit switch vibration endurance testing with plant level data
  - Results showed minimal wear for simulated one cycle operation that resulted in no impact to valve function

# Independent Reviews

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- Each individual component evaluation was subjected to an independent review
  - The purpose was to ensure that the analytical methods, assumptions, judgment, and conclusions were reasonable
  - Reviews were performed by MPR Associates and Stevenson and Associates personnel
- Conclusions were that the assessments, combined with the planned testing (i.e., shaker table), would provide the desired assurance that evaluated components are capable of performing satisfactorily for a full cycle of EPU full thermal power operation

# Summary

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- The completed vibration evaluations provide assurance that potentially affected components will perform acceptably for at least a full 24-month cycle at EPU full thermal power operation
  - All evaluations and testing are completed except for the Target Rock S/RV
  - Implementation of actions is either planned or complete to support return of the QC units to full EPU power operation
    - Detailed walkdowns
    - Installations of upgraded ERVs and Target Rock S/RV
    - New steam dryer
  - DR evaluations support continued full EPU power operation
    - Detailed walkdowns
    - Installation of Target Rock S/RV upgrade and enhancements to steam dryer

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# EPU Vulnerability Review

Mohammad Molaei
Dresden Engineering Programs Manager

# Topics

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- Mission and Goals
- Process Used
- Systems Reviewed
- Potential Vulnerabilities and Actions
- Conclusions
- Summary

# Mission and Goals

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- Mission – identify potential EPU-related vulnerabilities for DR and QC, and actions to prevent failures induced by those vulnerabilities
- Goal – eliminate operational challenges, as measured by
  - Licensee Event Reports
  - Engineered safety features actuations
  - Reactor scrams
  - Plant power derates
  - Unplanned entries into Technical Specifications
  - Operator work-arounds or challenges (increases risk of one of the above events)
  - Unexpected accelerated degradation (that increases risk of one of the above events)
  - Loose/lost parts

# Process Used
## Power and Safety Systems

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- Power Systems
  - Phase I - Data Collection and interviews
  - Phase II - System Level and Component Level Evaluations
  - Phase III - Vulnerability Assessments and Recommendations
- Safety Systems
  - Event input verification
  - Task report output implementation validation
  - Effect of power operation at EPU condition on safety components
- A total of 42 power systems and 10 safety systems were reviewed

# Process Used
## Technical Rigor

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- For the purpose of this review, the components in the plant were assumed to be susceptible to failure, unless proven otherwise
- Evaluated changes in operating parameters post-EPU for four units
  - Flow rate, temperature, pressure, radiation level, vibration level, and wear rate
- Utilized process of elimination at system and component levels
- Identified potential vulnerabilities due to the changed parameters
- Developed actions to address the potential vulnerabilities
- Results were challenged in multiple stages, by various teams
- Utilized multiple industry organizations

# Systems Reviewed
## Power Systems

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- Reactor Recirculation and Vessel Internals
- Main Steam
- Off Gas
- Feedwater
- Feedwater Level Control
- Condensate
- Condensate Booster
- Condensate Demineralizer
- Main Generator
- Generator Hydrogen Cooler
- Stator Cooling
- Isolated Phase Bus Duct
- Instrument Air
- Reactor Building Closed Cooling Water
- Turbine Building Closed Cooling Water
- Spent Fuel Pool Cooling
- Shutdown Cooling/Residual Heat Removal
- Radwaste
- Circulating Water
- Reactor Building Equipment Drain
- Turbine Building Equipment Drain
- Hydrogen Addition
- Zinc Injection
- Service Water
- Reactor Water Clean Up
- Nuclear Instrumentation
- Control Rod Drive
- Reactor Building Ventilation
- Turbine Building Ventilation
- Control Room Ventilation
- Extraction Steam
- Heater Drain
- Misc. Heater Vents and Drains
- Turbine Oil
- Main Turbine
- EHC
- Main Condenser
- Onsite Power
- Offsite Power
- Process Radiation Monitoring
- DC Power
- Main Generator Exciter

# Systems Reviewed
## Safety Systems

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- Automatic Depressurization System (ADS)
- Containment
- Core Spray (CS)
- Emergency Diesel Generator (EDG)
- High Pressure Coolant Injection (HPCI)
- Isolation Condenser (IC)
- Low Pressure Coolant Injection (LPCI)/Residual Heat Removal (RHR)
- Reactor Core Isolation Cooling (RCIC)
- Standby Gas Treatment (SBGT)
- Standby Liquid Control (SLC)

# Potential Vulnerabilities and Actions

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1. Components susceptible to increased vibration due to increased FW flow
   - Perform a visual inspection of a sample of separator stand pipe welds to the shroud head
   - Perform a visual inspection of the FW sparger end bracket pin
2. Components susceptible to increased vibration due to increased core differential pressure (d/p)
   - Establish the value of core d/p at which slip joint bypass leakage initiates jet pump vibration
   - Accelerate the Boiling Water Reactor Vessel Internals Project (BWRVIP)-41 required inspection of the restrainer gate wedges for evidence of wear

# Potential Vulnerabilities and Actions (cont.)

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3. Enhance PMs to address increased wear
   - Accelerate generator PM
   - Increase recirculation pump/drive motor/motor generator set PMs
   - Enhance valve internals and actuator PMs in the systems with changed parameters
   - Replace one high flow switch in each MSL, inspect for signs of degradation and adjust PM accordingly
   - Inspect offgas condenser division plate bypass valve
   - Perform eddy current testing of a sample of unstaked tubes at the staked region of the main condenser

# Potential Vulnerabilities and Actions (cont.)

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4. Increased vibration caused by increased flow and Recirculation pump speed
   - Perform a one-time inspection of the internals of the stator cooling temperature controller
   - Install flex hoses on all cooling lines to the condensate and condensate booster pump bearings and the FW pump seals
   - Perform a one-time inspection of electrical connections/mechanical linkages subject to turbine control valve vibrations
   - Perform one-time vibration measurements on susceptible small bore FW piping at various designated power levels
   - Inspect the recirculation loop flow sensing lines and other small-bore piping in the drywell after recirculation pump speeds are increased to levels not previously attained

# Potential Vulnerabilities and Actions (cont.)

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5. Gradual component degradation from less than optimum FW and condensate pump configurations
   - Perform a one-time boroscope examination of all four condensate pump impellers during the next refueling outage
   - Install proximity probe or ultrasonic flow measuring device to accurately assess pump impeller degradation
   - Assess the feasibility of two FW pumps and three condensate/condensate booster pumps combination
   - For current operating configuration, perform analysis and validation testing to identify optimum operating conditions to start and stop condensate/condensate booster and feedwater pumps
   - Increase the PM frequency for FW pump seal replacement to two years from the current four years

# Potential Vulnerabilities and Actions (cont.)

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6. Increased FW and condensate flow on balance-of-plant valves and internal components
   - Perform sizing calculation for the condensate/condensate booster minimum flow valve
   - Perform sizing calculation for the high pressure (HP) and low pressure (LP) heater inlet, outlet, and bypass motor-operated valves
   - Evaluate the temperature element thermowells in the condensate, condensate booster, and FW systems; also assess the hydrogen and oxygen injection quills
   - Redesign and install the condensate and FW system sample probes

# Potential Vulnerabilities and Actions (cont.)

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7. Increased flow accelerated corrosion (FAC) due to increased FW flow
   - Determine the cause of the higher than expected condensate influent iron concentration in DR3; inspect LP heater casing for effects of corrosion
   - Measure pipe wall thickness at susceptible locations to validate the EPU assumptions in the FAC program
   - Evaluate the outage template for control rod vacuuming and increase frequency if necessary
   - During scheduled control rod drive hydraulic control unit overhauls, inspect the inlet and outlet filters for plugging
   - Institute programmatic FW heater and flash tank non-destructive examination inspections on a three-cycle frequency

# Potential Vulnerabilities and Actions (cont.)

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8. Existing system performance issues were exacerbated by EPU implementation
   - Restore margin and eliminate abnormal operating condition for the heater drain system
   - Perform main condenser tube cleaning and waterbox de-sludging if monitoring parameters indicate the presence of scale or debris
   - Resolve the overpressure condition on LP heaters and the drain coolers
   - Optimize FW level control system performance by developing an analytical model considering various pump combinations and power levels

# Potential Vulnerabilities and Actions (cont.)

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9. Post-EPU operating and analytical margins have been reduced
   - Monitor cross-around relief valves for leakage after any pressure transient within the turbine boundary
   - Reevaluate task report recommendation to operate with full offgas condenser condensate flow
   - Identify systems or analyses with limited post-EPU margin and evaluate/implement actions to increase margin

# Conclusions
## Safety Systems

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- Functions of safety systems remain uncompromised
- Design inputs used in analyses are conservative due to the fifth unit model; the fifth unit model results in overly conservative calculated margin in some cases
- Analyses results have been adequately implemented with the exception of changing residual heat removal motor lubrication oil at QC; not an issue due to current operation at pre-EPU power levels
- Some documentation deficiencies were discovered during the review that are being resolved through the corrective action program

# Conclusions

## Power Systems

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- Found no vulnerabilities that posed an immediate challenge to plant operation
- 101 actions were identified to improve operating margin and prevent future failures
- Most of the actions address accelerated equipment aging or wear due to EPU

# Summary

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- Rigorous and comprehensive review was conducted
- Extensive corrective actions were developed during the review
- Vulnerability review relied on EPU assessment, previously addressed, for evaluation of vibration effects on MS piping and components
- Considerable knowledge was gained during the review on impact of EPU operation and was shared with the industry
- Safety system review, while focused, confirmed the adequacy of the original licensing analysis for EPU
- Review concluded that safe and reliable EPU operation is achievable for DR and QC

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# FW Sample Probes

Linda Dyas
Dresden Equipment/Programs Specialist

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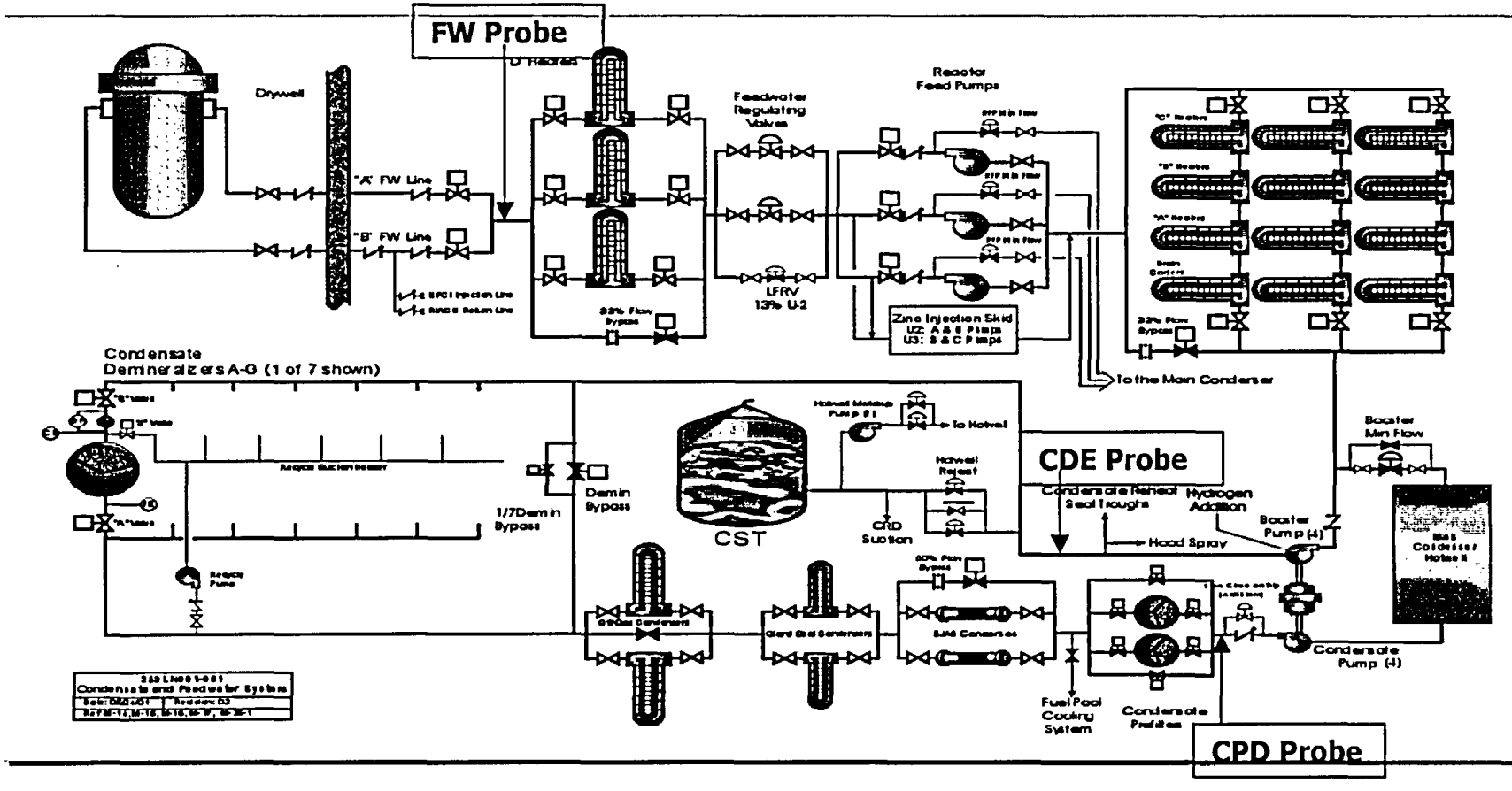

# Dresden Probe History

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Unit 2

- Failed FW probe damaged the FW sparger in October 2003 - probe removed and damage repaired
- Failed condensate demineralizer effluent (CDE) probe damaged the condensate booster pump in October 2003 – probe removed, and pump casing and impeller replaced
- Condensate pump discharge (CPD) probe was replaced as part of condensate pre-filter modification in 2001

Unit 3

- Two FW probes were discovered and removed from FW sparger in December 2003
- CDE probe was removed and replaced in December 2003
- CPD probe was replaced as part of pre-filter modification in 2002

# Schedule for Probe Replacement

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| | Dresden | | Quad Cities | |
|---|---|---|---|---|
| | Unit 2 | Unit 3 | Unit 1 | Unit 2 |
| **FW Probe** | Oct 2005* | Nov 2004 | April 2005 | Complete |
| **CDE Probe** | Oct 2005 | Nov 2004 | April 2005 | Complete |
| **CPD Probe** | Complete** | Complete** | April 2005 | Complete |

* FW probe retrieval planned during October 2005 refueling outage on DR2

** Steam jet air ejector intercondenser water box inspections during DR2 and DR3 refueling outages to ensure CPD probe did not fail prior to the pre-filter modification

# Current Dresden Status

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- Operability determination was performed prior to DR2 restart in December 2003
- Lost parts evaluation for DR2 and DR3 FW sample probes was performed in December 2003
- Both evaluations concluded that safe reactor operation will not be compromised

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# Planned Actions/Outage Scopes

James Meister
Vice President, Nuclear Services

# Planned Actions/Outage Scopes
## (Vibration Assessments)

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- Validate PM scope and frequency for all evaluated components
  - ERV PM changes already implemented
- Replace ERV actuator parts for both DR and QC during future rebuilds
- Inspect ERV actuator internals each refueling outage until performance is validated
- Perform focused walkdowns during each refueling outage
- Inspect minimum of one MSIV internally each refueling outage until satisfactory performance is demonstrated
- Install upgraded Target Rock S/RVs

# Planned Actions/Outage Scopes
## (DR Fall 2004 Outage/QC Spring 2005 Outage )

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- Inspection
  - In-vessel visual inspections
    - QC1 steam dryer lost part
  - Boroscopic inspections
  - Internal valve inspections
  - Walk-downs
  - NDE inspections
  - Eddy current testing
  - MSL flow d/p switch
- Modifications:
  - Steam dryer modification/replacement
  - Sample probes
  - Flex hoses
  - 2x1 welds
  - Orifice resizing
  - Data recorders

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# Closing Remarks

James Meister
Vice President, Nuclear Services

# Closing Remarks

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- Vibration assessment and extent of condition review provide assurance that potentially affected components will perform acceptably for at least a full 24-month cycle at EPU full thermal power operation
- Considerable knowledge was gained during the review on impact of EPU operation and was shared with the industry
- Functions of safety systems remain uncompromised
- Exelon is taking aggressive action to address EPU-related issues, including locating and retrieving loose parts
- Exelon remains confident that EPU can be implemented safely and reliably for the long run at DR and QC